

**APPLICATION
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Applicant:

Jochen C. Beintner, et al.

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**“A Pull-Back Method of Forming
Fins in FinFETs”**

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**INTERNATIONAL BUSINESS
MACHINES CORPORATION
ARMONK, NEW YORK 10504**


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3 A Pull-back Method of Forming Fins in FinFETs
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6 TECHNICAL FIELD
7

8 The field of the invention is that of fabricating field effect transistors having
9 a body extending perpendicular to the semiconductor substrate between
10 horizontally disposed source and drain regions, referred to as a "FinFET".
11
12

13 BACKGROUND OF THE INVENTION
14

15 Metal-Oxide-Semiconductor field effect transistor (MOSFET) technology is
16 the dominant electronic device technology in use today. Performance
17 enhancement between generations of devices is generally achieved by
18 reducing the size of the device, resulting in an enhancement in device speed.
19 This is generally referred to as device "scaling".
20

21 Ultra-large-scale integrated (ULSI) circuits generally include a multitude of
22 transistors, such as more than one million transistors and even several

1 million transistors that cooperate to perform various functions for an
2 electronic component. The transistors are generally complementary metal
3 oxide semiconductor field effect transistors (CMOSFETs) which include a
4 gate conductor disposed between a source region and a drain region. The
5 gate conductor is provided over a thin gate oxide material. Generally, the
6 gate conductor can be a metal, a polysilicon, or polysilicon/germanium
7 ($\text{Si}_x \text{Ge}_{(1-x)}$) material that controls charge carriers in a channel region
8 between the drain and the source to turn the transistor on and off. The
9 transistors can be N-channel MOSFETs or P-channel MOSFETs.

10

11 In bulk semiconductor-type devices, transistors such as MOSFETs, are built
12 on the top surface of a bulk substrate. The substrate is doped to form source
13 and drain regions, and a conductive layer is provided between the source
14 and drain regions. The conductive layer operates as a gate for the transistor;
15 the gate controls current in a channel between the source and the drain
16 regions. As transistors become smaller, the body thickness of the transistor
17 (or thickness of depletion layer below the inversion channel) must be scaled
18 down to achieve superior short-channel performance.

19

20 As MOSFETs are scaled to channel lengths below 100 nm, conventional
21 MOSFETs suffer from several problems. In particular, interactions between
22 the source and drain of the MOSFET degrade the ability of the gate to

1 control whether the device is on or off. This phenomenon is called the
2 "short-channel effect".
3
4 Silicon-on-insulator (SOI) MOSFETs are formed with an insulator (usually,
5 but not limited to, silicon dioxide) below the device active region, unlike
6 conventional "bulk" MOSFETs, which are formed directly on silicon
7 substrates, and hence have silicon below the active region.
8
9 Conventional SOI-type devices include an insulative substrate attached to a
10 thin-film semiconductor substrate that contains transistors similar to the
11 MOSFETs described with respect to bulk semiconductor-type devices. The
12 insulative substrate generally includes a buried insulative layer above a
13 lower semiconductor base layer. The transistors on the insulative substrate
14 have superior performance characteristics due to the thin-film nature of the
15 semiconductor substrate and the insulative properties of the buried
16 insulative layer. In a fully depleted (FD) MOSFET, the body thickness is so
17 small that the depletion region has a limited vertical extension, thereby
18 eliminating link effect and lowering hot carrier degradation. The superior
19 performance of SOI devices is manifested in superior short-channel
20 performance (i.e., resistance to process variations in small size transistors),
21 near-ideal subthreshold voltage swing (i.e., good for low off-state current
22 leakage), and high saturation current. SOI is advantageous since it reduces

1 unwanted coupling between the source and the drain of the MOSFET
2 through the region below the channel. This is often achieved by ensuring
3 that all the silicon in the MOSFET channel region can be either inverted or
4 depleted by the gate (called a fully depleted SOI MOSFET). As device size
5 is scaled, however, this becomes increasingly difficult, since the distance
6 between the source and drain is reduced, and hence, they increasingly
7 interact with the channel, reducing gate control and increasing short channel
8 effects (SCE).

9
10 The double-gate MOSFET structure is promising since it places a second
11 gate in the device, such that there is a gate on either side of the channel.
12 This allows gate control of the channel from both sides, reducing SCE.
13 Additionally, when the device is turned on using both gates, two conduction
14 ("inversion") layers are formed, allowing for more current flow. An
15 extension of the double-gate concept is the "surround-gate" or "wraparound-
16 gate" concept, where the gate is placed such that it completely or almost-
17 completely surrounds the channel, providing better gate control.

18
19 In accordance with the invention a method is provided for fabricating a
20 double gate field effect transistor (FinFET) which is compatible with
21 conventional MOSFET fabrication processes. The device channel comprises
22 a thin silicon fin standing on an insulative layer (e.g. silicon oxide) with the

1 gate in contact with the sides of the fin. Thus inversion layers are formed on
2 the sides of the channel with the channel film being sufficiently thin such
3 that the two gates control the entire channel film and limit modulation of
4 channel conductivity by the source and drain.
5
6 The double gates on the channel fin effectively suppress SCE and enhance
7 drive current. Further, since the fin is thin, doping of the fin is not required
8 to suppress SCE and undoped silicon can be used as the device channel,
9 thereby reducing mobility degradation due to impurity scattering. Further,
10 the threshold voltage of the device may be controlled by adjusting the work
11 function of the gate by using a silicon-germanium alloy or a refractory metal
12 or its compound such as titanium nitride.
13 Generally, it is desirable to manufacture smaller transistors to increase the
14 component density on an integrated circuit. It is also desirable to reduce the
15 size of integrated circuit structures, such as vias, conductive lines,
16 capacitors, resistors, isolation structures, contacts, interconnects, etc. For
17 example, manufacturing a transistor having a reduced gate length (a reduced
18 width of the gate conductor) can have significant benefits. Gate conductors
19 with reduced widths can be formed more closely together, thereby
20 increasing the transistor density on the IC. Further, gate conductors with
21 reduced widths allow smaller transistors to be designed, thereby increasing
22 speed and reducing power requirements for the transistors.

1 Heretofore, lithographic tools are utilized to form transistors and other
2 structures on the integrated circuit. For example, lithographic tools can be
3 utilized to define gate conductors, active lines conductive lines, vias, doped
4 regions, and other structures associated with an integrated circuit. Most
5 conventional lithographic fabrication processes have only been able to
6 define structures or regions having a dimension of 100 nm or greater.

7
8 In one type of conventional lithographic fabrication process, a photoresist
9 mask is coated over a substrate or a layer above the substrate. The
10 photoresist mask is lithographically patterned by providing electromagnetic
11 radiation, such as ultraviolet light, through an overlay mask. The portions of
12 the photoresist mask exposed to the electromagnetic radiation react (e.g. are
13 cured). The uncured portions of the photoresist mask are removed, thereby
14 transposing the pattern associated with the overlay to the photoresist mask.
15 The patterned photoresist mask is utilized to etch other mask layers or
16 structures. The etched mask layer and structures, in turn, can be used to
17 define doping regions, other structures, vias, lines, etc.

18
19 As the dimensions of structures or features on the integrated circuit reach
20 levels below 100 nm or 50 nm, lithographic techniques are unable to
21 precisely and accurately define the feature. For example, as described
22 above, reduction of the width of the gate conductor (the gate length)

1 associated with a transistor or of the active lines associated with an SOI
2 transistor has significant beneficial effects. Future designs of transistors
3 may require that the active lines have a width of less than 50 nanometers.
4
5 Double gate SOI MOSFETs have received significant attention because of
6 its advantages related to high drive current and high immunity to short
7 channel effects. The double-gate MOSFET is able to increase the drive
8 current because the gate surrounds the active region by more than one layer
9 (e.g., the effective gate total width is increased due to the double gate
10 structure). However, patterning narrow, dense active regions is challenging.
11 As discussed above with respect to gate conductors, conventional
12 lithographic tools are unable to accurately and precisely define active
13 regions as structures or features with dimensions below 100 nm or 50 nm.
14
15 Thus, there is a need for an integrated circuit or electronic device that
16 includes smaller, more densely disposed active regions or active lines.
17 Further still, there is a need for a ULSI circuit which does not utilize
18 conventional lithographic techniques to define active regions or active lines.
19 Even further still, there is a need for a non-lithographic approach for
20 defining active regions or active lines having at least one topographic
21 dimension less than 100 nanometers and less than 50 nanometers (e.g., 20-
22 50 nm). Yet further still, there is a need for an SOI integrated circuit with

1 transistors having multiple sided gate conductors associated with active
2 lines having a width of about 20 to 50 nm.

3

4 The present invention is directed to a process for fabricating FinFET
5 transistor structures which is an extension of conventional planar MOSFET
6 technology and resulting structures.

7

8

9 SUMMARY OF THE INVENTION

10

11 The present invention is directed to a process for fabricating FinFET
12 transistor structures, in which the vertical silicon slices that contain the
13 transistor body (referred to as fins) are defined in a self-aligned fashion
14 relative to a block of silicon, so that the fin width does not depend on
15 tolerances in alignment, but on a material removal process.

16

17 A feature of the invention is the definition of a set of blocks of silicon that
18 will be processed to form two fins for FinFET transistors.

19

20 Another feature of the invention is the removal from an oversized block of
21 silicon of material between the final locations of fins, leaving the fins
22 remaining as the un-etched material.

1 Another feature of the invention is a self-aligned process in which a
2 hardmask is reduced in width by an amount that will be the width of the
3 fins, so that the width of the fins is determined by the material removal
4 process.

5
6 Yet another feature of the invention is a process in which a first hardmask is
7 formed with a width that will be discarded and a second hardmask is formed
8 by deposition of a conformal material about the first hardmask

9
10
11 BRIEF DESCRIPTION OF THE DRAWINGS

12
13 Figure 1 shows in cross section a preliminary step in the process of forming
14 the invention, showing silicon blocks that will each form two fins.

15
16 Figure 2 shows the same area after a pull-back operation that reduces the
17 width of the hardmask.

18
19 Figure 3A shows the area after an optional step to remove one of the fins,
20 producing an odd number of fins.

21
22 Figure 3B shows the area after stripping the hardmask.

1 Figure 4 shows the area after etching out the blocks to form the fins.
2
3 Figure 5 shows a set of fins ready for formation of the transistor gates.
4
5 Figure 6 shows a first step in an alternative method.
6
7 Figure 7 shows widening the aperture.
8
9 Figure 8 shows filling the aperture with a second hardmask.
10
11 Figures 9A, 9B and 9C show cross sections at the end and middle of the fins
12 after stripping the nitride.
13
14 Figures 10A, 10B and 10C show cross sections at the end and middle of the
15 fins after etching the device layer.
16
17 Figures 11A, 11B and 11C show cross sections at the end and middle of the
18 fins after depositing an alternative layer.
19
20 Figures 12A, 12B and 12C show cross sections at the end and middle of the
21 fins after cleaning up residual oxide.
22

1 DETAILED DESCRIPTION

2

3 This invention describes a process for forming controlled, thin body fins for
4 a FinFET device, in which the uniformity of the thickness of the fins does
5 not depend on alignment of a stepper. The process uses a pullback step that
6 defines the width of the hardmask that sets the thickness of the fin.

7 Thickness control of the fin body is a critical factor in the fabrication
8 process, as it directly results in FET threshold variation.

9

10 This specification describes two integration schemes of the pullback fin
11 process, the first scheme is implemented in a self-aligned source/drain
12 process flow and the second in a source/drain block process flow.

13

14 In each case, the starting point is a SOI or bulk silicon wafer. In the case of
15 a SOI wafer, the fin height will be determined by the thickness of the
16 silicon. The layer of semiconductor that contains the fins will be referred to
17 as the fin layer, whether the substrate is bulk or SOI.

18

19 Referring now to Figure 1, there is shown in cross section a portion of an
20 integrated circuit that will contain a set of FinFET transistors. Wafer 10
21 may be bulk silicon or an SOI wafer. The SOI wafer is preferred and is
22 illustrated here. Above substrate 10, buried oxide insulator (BOX) layer 20

1 has been formed by conventional processes. Sitting on top of BOX 20 are
2 blocks of silicon 50 extending perpendicular to the plane of the paper that
3 will form the fins of FinFETs. The plane of the cross section is taken
4 through the location where transistor gates will be placed in later steps. The
5 horizontal dimensions appearing in the cross section will be referred to as
6 transverse dimensions.
7
8 Blanket implants may be done at any convenient time.
9
10 Illustrative ranges for the SOI silicon thickness are 100Å to 2000Å. A
11 thermal oxide 52 is grown to a thickness of 300Å (ranging between 50Å-
12 1000Å) on the surface of the silicon using thermal diffusion processes.
13 Alternatively the oxide can be deposited with the same thickness using
14 CVD processes. A CVD nitride cap 54 is deposited on the oxide with a
15 thickness of 1000Å (Range 300Å - 2000Å).
16
17 The oxide/nitride stack shown in Figure 1 has been lithographically
18 structured to define silicon blocks. With the resist in place, the nitride and
19 the oxide are etched in a first RIE plasma etch, then the silicon is etched in a
20 second RIE plasma etch with the nitride 54 masking the silicon layer 50.
21 Whether any resist remains after the first etch will depend on details of the
22 process parameters. The width of the structure is shown as bracket 56 in

1 Figure 1. The etching chemistry and parameters are conventional, well
2 known to those skilled in the art. It is important that both etches are very
3 straight, as is conventional in the art, so that sidewall angles close to 90
4 degree are generated. Significant variation in the angle of the vertical faces
5 will result in thickness variation of the fins and thus of the transistor bodies.
6
7 In the case of SOI wafers, the silicon etch is a conventional etch that is
8 selective to oxide and stops on the BOX (Buried oxide). In the case of bulk
9 silicon the silicon etch is timed. The result of forming silicon fin blocks is
10 shown in Figure 1. At this point it is also possible to do any kind of one-
11 sided fin processing, e.g. ion implantation, thereby adding an additional
12 degree of freedom for FinFET device design.
13
14 The term “one-sided” is used because the left and right vertical surfaces of
15 each block 50 will become corresponding sides of separate fins in the final
16 structure. The opposite sides of the fins are at this stage buried within
17 blocks 50. Figure 4 shows the first exposure of the other sides of the final
18 fins. If ion implantation were used at this time, only the vertical surfaces
19 shown in Figure 1 would be affected because the portion of block 50 that
20 will become the second exposed surface of a fin is covered. This could be
21 used to make the channel or threshold on one side of the FinFET different
22 from that on the other side.

1 In the following steps, the central portion of the silicon fin blocks 50 will be
2 removed, leaving the outside portions as the fins. Thus, the difference
3 between dimension 56 and the thinner dimension 53 shown in Figure 2 sets
4 the thickness of the fins.
5
6 Referring now to Figure 2, the pad nitride 54 is pulled back using a wet etch
7 process (e.g. HF EG (hydrofluoric acid mixed with ethylene glycol)) or an
8 isotropic plasma etch selective to silicon. The amount of pullback on either
9 side of nitride cap 54 defines the fin body thickness later in the process.
10
11 A typical composition of the etching fluid is about 25 parts EG to 1 part of
12 49% HF at 80 degrees C. The composition and temperature are not critical
13 and a wide range of parameters is satisfactory.
14
15 HF EG also pulls the oxide back. This is not critical as there will be an
16 oxide deposited on top of it later.
17
18 It is an advantageous feature of the invention that the pull back step is not
19 required to etch the nitride 54 and the oxide 52 at exactly the same rate,
20 which would be very difficult to achieve.
21
22 In Figures 3A and 3B, a CVD oxide film 70 (e.g. TEOS) has been deposited

1 to fill the spaces between the silicon blocks 50. Oxide 70 is then planarized
2 down to the nitride 54 on top of the oxide/silicon by chemical-mechanical
3 polishing (CMP) or any other known planarization technique. This oxide
4 70 has preferably a higher wet or plasma etch rate than the BOX, so that the
5 BOX will function as an etch stop in a future oxide etch. Film 70 is referred
6 to as a second hardmask.

7
8 Figure 3A also shows the result of an optional lithography step that is used
9 to open up an etch window 57 to etch oxide on one side of the
10 nitride/oxide/silicon block structure. This fin-removal step is convenient to
11 be able to process an odd amount of fins for better current quantization for
12 the FinFET. Those skilled in the art are aware that one FinFET transistor
13 can be formed from several fins connected in parallel. The circuit designer
14 will calculate the current required for each transistor and specify the number
15 of fins required to produce that current. If the fins are processed using a
16 pullback process, as shown here, two fins are formed for each
17 nitride/oxide/silicon block.

18
19 If the circuit is not sensitive to the amount of transistor current, it may be
20 preferable to have an arrangement with only even numbers of fins. The fin-
21 removal step shown in preparation in Figures 3A and 3B will be used when
22 the extra cost of the litho step is required by the demands of the circuit.

1 The result of the step shown is that the fin below aperture 57 that would
2 have been defined in Figure 4 will be removed (or not defined), leaving one
3 fin for that block. The oxide etch for aperture 57 is timed and has to etch
4 down at least to the oxide 52 level below the nitride 54 on top of the silicon.
5
6 Next, as shown in Figure 3B, the nitride 54 is removed using a wet etch
7 (e.g. hot phosphoric acid) or a plasma etch. In the same Figure 3B, the oxide
8 on top of the silicon is removed by an oxide RIE etch. This etch should be
9 very anisotropic to avoid significant lateral removal of the oxide 70
10 overlapping the silicon. For convenience in exposition, brackets 65 denote
11 the nominal width of the fins to be formed in silicon blocks 50 B in one case
12 set by the difference in the edges of aperture 66 and the edges of block 50A
13 and in the other, by the difference in one edge of aperture 63 and edge 51B
14 of block 50B. The width 64 of aperture 66 has been set by the reduced width
15 53 of the nitride caps (see Fig. 2). A different reference numeral is used to
16 emphasize that the two dimensions are not exactly equal.
17
18 In practice, the pullback of oxide 52 will not be exactly the same as that of
19 nitride 54, so aperture 66 will be slightly larger or smaller as it passes
20 through the former location of layer 52 than the portion of aperture 66 that
21 passes through layer 54. It is advantageous that this difference does not
22 matter.

1 If aperture 66 is larger, for example, as it passes through the former location
2 of layer 52 than it is higher up, the directional nature of the etch means that
3 the aperture cut in the silicon 50 is not increased in width by the wider
4 aperture in the former location of layer 52 above it. If the aperture 66 in
5 that location is smaller, the etch through layer 50 will be delayed at the
6 edges by etching through the edge of layer 52 that should have been
7 removed. This will leave some residual silicon at the bottom of the aperture,
8 but a standard overetch will clean up the bottom corners of the aperture in
9 layer 50.

10

11 Variation in the magnitude of dimension 64 would be another variable in fin
12 body thickness control and would reduce uniformity in the final product. If,
13 in a particular application, it is not practical to eliminate horizontal etching
14 of oxide 70 during the step of removing oxide 52, the nitride pullback can
15 be reduced in magnitude such that the net dimension 64 is correct, since a
16 lateral etch component can be considered as a fixed bias and compensated
17 for.

18

19 It has been found that, for a process having a 90nm groundrule, variation in
20 final fin thickness was 3% lot to lot (1 sigma) and that variation within a
21 wafer was only 1%. Those skilled in the art will readily appreciate that this
22 improvement in uniformity will result in improved circuit performance.

1 On the left of Figure 3B, aperture 63 has a right edge that is offset from
2 edge 51B of silicon block 50B by substantially the same amount as the
3 offset between the right edge of aperture 66 and edge 51A of silicon 50A.
4 The position of the left edge of aperture 63 is not critical in this case.
5
6 Figure 4 shows the result of etching, in a conventional RIE etch, silicon
7 blocks 50 selective to oxide, using oxide 70 as a mask. Again, it is
8 important that the RIE etch produces substantially straight (e.g. substantially
9 perpendicular to the horizontal surface of silicon blocks 50) silicon side
10 walls of fins 55, so that the dimension 65 is uniform. Because of aperture
11 57 in Figure 3A, there is only one fin in the left aperture.
12
13 Thus, the process discussed thus far (illustrated in Figs 1 B 4) involves
14 defining blocks of silicon that have a width equal to the distance between
15 outer edges of a pair of fins to be defined in silicon blocks 50. The
16 hardmask (nitride 54 and oxide 52) used in that step is pulled back on each
17 side by an amount proportional in width to the width of a fin. The amount
18 of pullback on each side in general will not be exactly equal because there
19 may be some etch bias from other processes.
20 Figure 5 shows the result of removing oxide 70 using a wet etch (e.g. HF) or
21 plasma etch, so that silicon fin structures 55 remain. The etch process is
22 selective to silicon and to the BOX. A typical fill material of LPCVD TEOS

1 oxide etches more than four times as fast as thermal oxide in HF, so that
2 there is a clear difference between the fill and the BOX.

3

4 The process continues with the selfaligned source/drain SARC2 process
5 flow as shown in copending patent application YOR920030380,
6 incorporated by reference in its entirety, or with any other conventional
7 process for putting a gate on a FinFET.

8

9 The remaining Figures illustrate an alternative process that is generally
10 similar to the previously described process flow.

11

12 The starting point is the same as that described in Figure 1, with a SOI or
13 silicon bulk substrate and an oxide and nitride stack.

14

15 In Figure 6, the same basic wafer structure with substrate 10, BOX 20, SOI
16 layer 50, pad oxide 52 and pad nitride 54 has been patterned with the
17 opposite polarity compared to the embodiment described in Figure 1. Here
18 the block area is etched, while in the previous embodiment, the block area
19 was remaining. Two fin separation apertures 110, having a width 164,
20 illustratively the same as width 64 in the previous version, have been etched
21 down to BOX 20.

22

1 Figure 7 shows the nitride pullback to form apertures 115, using the same
2 technology as in Figure 2. The result of this step is that the lower portion of
3 apertures 115 has the dimension 164 of the spacing between fins and the
4 upper portion of aperture 115 has been expanded to have the spacing 156
5 between edges that is the outside-to-outside dimension of a pair of fins.
6 Dimension 165 (the amount of nitride pullback) is the thickness of the fins
7 to be formed in SOI 50 in subsequent processing steps.
8
9 Figure 8 shows the result of depositing and planarizing another layer of
10 oxide 180, filling the aperture 115. Oxide 180 will be the hardmask to
11 define the outer edges of the fins. At this point it would be also possible to
12 generate an odd amount of fins by using the same processes as described in
13 Figures 3A and 3B.
14
15 Figures 9A, 9B and 9C show an alternative step that applies to both
16 embodiments in which the source/drain blocks 50 are lithographically
17 structured. This step may be performed before Figure 1 in the present
18 disclosure. Figure 9A shows a top view, with two oxide blocks 180
19 extending North-South and two blocks 54 that extend E-W and cover the
20 ends of the fins. The final fins will be formed under the N-S edges of
21 blocks 180. Figure 9A is shown after a preliminary step of etching
22 apertures through nitride 54, oxide 52 and silicon 50 and filling them with

1 oxide to form blocks 180. Figure 9 also includes two cross sections
2 indicated as 9B and 9C. In this step, the nitride 54 has been etched in the
3 middle of the structure, where the gate will be placed and along line 9C,
4 using an oxide selective RIE. The nitride 54 remains as a hardmask in the
5 source/drain block areas at the top and bottom of Figure 9A, where it
6 prevents the silicon etching in a later step from cutting the East-West cross
7 connections between fins. The purpose of this optional step is to tie
8 together the sources and drains of a set of fins that collectively form a
9 transistor with higher current capacity than an individual fin can carry. The
10 word Aset@ means one or more, as used in the following claims, which are
11 not restricted to pairs of fins.

12

13 Figure 9C shows that oxide blocks 180 have been formed, projecting above
14 oxide 52 on top of the silicon layer 50. Blocks 180 will serve as a hardmask
15 in the subsequent oxide/silicon etching step that will define the fins. Figure
16 9B shows that the nitride remains at the N and S ends of the structure, so
17 that an E-W portion of layer 50 will remain to connect pairs of fins in that
18 region. Those skilled in the art will readily be able to adapt the process of
19 Figures 1 B 4 to preserve the E-W portion of layer 50 at the ends of the fins.

20

21 In Figure 10C, the oxide 52 on top of the silicon 50 has been etched and the
22 silicon 50 has been removed outside the fin area, thus defining four fins 55.

1 Figure 10A shows again the top view. Figure 10B shows that the N and S
2 ends of the structure are unchanged, protected by the hardmask formed by
3 oxide 180 and nitride 54 and any residual amount of the block of resist that
4 was present in the previous step. Since layer 52 is much thinner than block
5 180, it does not matter if some of block 180 is removed during the removal
6 of layer 52. Figure 10B also shows that the oxide/silicon layer has been
7 trimmed outside the hardmask. Figure 10C shows the resulting structure
8 after oxide 52 and SOI 50 in Figure 9C have been etched, with oxide 180
9 acting as a hardmask. Since a highly directional etch is used in forming the
10 fins, a slight lateral etch of oxide will not be significant (and may be treated
11 as a bias in setting the width of block 180). Similar to the previous
12 embodiment (e.g. Figure 5), fins 55 are formed by etching the silicon blocks
13 50. Summarizing, oxide 180 filled the widened aperture 115 to protect one
14 side of the fin blocks and the fins 55 were defined by the same silicon etch
15 process as before.

16

17 The step next following Figure 10 will be the removal of the oxide 180.
18 Oxide 180 has been a deposited oxide, illustratively TEOS, which etches in
19 conventional processes at faster rate than the BOX, so that the process can
20 rely on the differential etch rate to permit exposing the BOX to an oxide
21 etch.

22

1 Figure 11 shows an alternative way to remove the deposited oxide 180
2 between the silicon structures, in case the oxide selectivity between the
3 deposited oxide and the BOX 20 is too low. In the alternative method, an
4 additional CVD oxide 190 is deposited and planarized the same way as
5 described above, so that Figure 11C shows the oxide 180 surrounded by the
6 new oxide 190. This process flow also prevents the silicon fins from being
7 exposed during the nitride etch in the next step. A nitride etch, for example
8 in hot phosphoric acid, can result in surface pitting. If the nitride is removed
9 using another silicon and oxide selective etch, e.g. a plasma etch, these steps
10 are not necessary.

11
12 Figure 12 shows the result of a cleanup operation in which the nitride 54 is
13 etched and the oxides 190 and 180 are removed selective to silicon using an
14 HF based etch chemistry, wet or vapor, or by oxide plasma etching. It is also
15 possible to etch first part of the oxide (e.g. 190), then remove the nitride 54,
16 followed by another oxide etch down to the BOX. This prevents overetching
17 into the BOX during the oxide etch. Figure 12C shows the separated fins 55
18 and Figure 12B shows the connecting block 55= connecting pairs of fins.

19
20 Each of the described processes then continues with a standard FinFET
21 process such as that described in J. Kedzierski et al., IEEE Transactions on
22 Electron Devices v.50 n.4 April 2003 p.952-958, or any other convenient

1 method of putting down gates on the fins and then performing standard back
2 end processing, well known to the art.

3

4 While the invention has been described in terms of a single preferred
5 embodiment, those skilled in the art will recognize that the invention can be
6 practiced in various versions within the spirit and scope of the following
7 claims.

8